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Soil Compaction Research Summary

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SOIL COMPACTION RESEARCH SUMMARY

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Soil compaction has become a major topic of discussion among scientists and crop producers in recent years. Even though some producers consider soil compaction to be a problem on their own farms, they feel resigned to the fact that there is little they can do to control it. Some recent solutions have been offered based on research efforts with soil compaction. There is significant interest in developing crop production systems with controlled traffic to help control the problem of soil compaction. There have also been new machine developments to address the problem of soil compaction, particularly with rubber tracked equipment and lower pressure tires.

The potential for soil compaction problems has increased in recent years as a result of use of larger, heavier field equipment. At the same time, average field size has increased as we have consolidated land holdings. This increases the potential for multiple soil types being found in each field. Even when the majority of the soils in the field are workable in the spring, some of the more poorly drained soils in the same field are probably too wet to be tilled properly.

We became interested in doing soil compaction research in Iowa in the early 1980s when we began to observe tracking patterns in many fields, particularly in fields with finer textured soils. We did not know if the delayed and/or poorer growth in fields with observable spring tillage tracks were significantly affecting total crop yields.

The purpose of this paper is to summarize some results of soil compaction research that has or is currently being conducted in Iowa, and to relate this information with other information obtained at other Midwest research studies.

SPRING TILLAGE EFFECTS

A study was initiated in 1984 on a private farm in the Mississippi River Bottom area between Fort Madison and Burlington, Iowa on a common river valley alluvial soil in the area, Chequest silt loam. This soil and many in the region where this research was conducted had shown evidence of spring tillage compaction from the tractor pulling a secondary tillage tool. In the experiment, seven track-type tractors ranging in weight from 13,500 lbs to 33,500 lbs were tested along with five wheeled tractors, ranging in weight from 14,000 lbs to 32,000 lbs. The purpose of the test was to evaluate the crop production and soil conditions in areas that had been trafficked compared to similar areas in the same area that had not been trafficked with a spring-tillage tractor pulling a field cultivator.

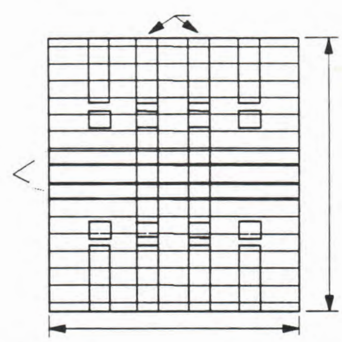

Figure 1. Trafficked and sampled areas in plot.

The layout of the plot is shown in Figure 1. Secondary tillage was perpendicular to the direction to the rows. A 16 row-30" planter was used to plant the plot areas after the plots were tilled with the various treatment tractors. Both crop and soil measurements were taken in each experimental plot area. There were 6 replications of 12 treatments in the study.

Corn emergence rate, plant height, and yield were all affected by traffic of tillage tractors. The yield reduction over all treatments and years was 13% in the areas that had been trafficked. The average yield reduction was 20% for the average loss from wheeled tractors and 11% for the tracked tractors.

Figure 2 illustrates the relative yields obtained in the traffic paths of the tractors compared to the yield obtained outside the travel path of the tractor. Yields in the traffic paths varied from 70% to 95% of the yields in non-trafficked areas. Losses were higher, in general, for the wheeled tractors than for tracked tractors.

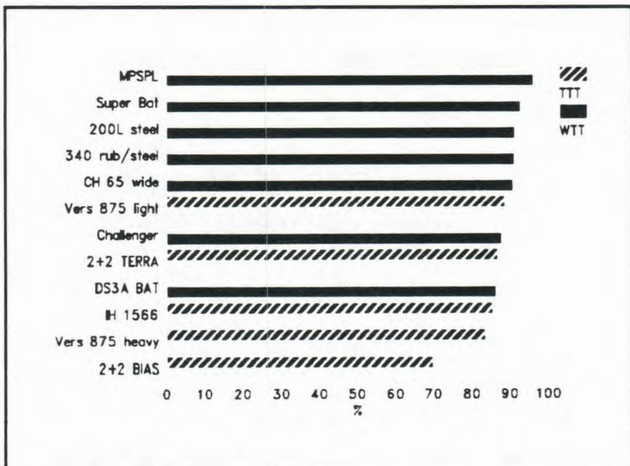

Figure 2. Relative yield loss for tractors, 1984-1987.

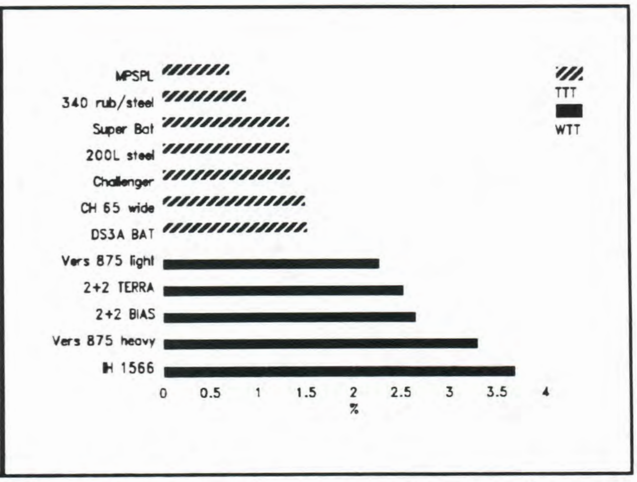

Figure 3. Yield reductions projections for each tractor.

Yield losses in trafficked areas shown in Figure 2 can be translated to field losses per tillage pass as shown in Figure 3. Figure 3 is calculated using information in Figure 2 assuming that each tractor was matched to an appropriate-sized field cultivator to match the tractor weight and power. Note that the highest field loss resulted from the use of a two-wheeled-drive tractor with dual tires. The only difference between the Vers 875 light and Vers 875 heavy was the ballast in the tires. This data indicates that leaving ballast in the tires can result in an approximate 1% yield loss per tillage pass.

FLEET STUDY

Results of the previous study indicate that lowered ground pressure on the soil during spring tillage passes may have had some beneficial effect. Therefore, a study was initiated in 1989 to simulate large-scale field effects of crop production with equipment fleets of different ground pressure. The fleets tested included machinery with tires, rubber tracks and low ground pressure tracks. The equipment fleets were set up such that tractors exerted 18, 6, or 2.5 pounds per square inch on the soil, while combines and grain wagons exerted 30, 7, and 4.5 psi, respectively for the various treatments. These treatments were identified as WT, TT and LGP fleets.

Three large field areas on the farm used in the previously described study were used as "field scale" experimental areas. Each of the three field areas were selected where soils, drainage, and fertility were uniform or had similar pattern across treatments. The three large fields were evenly divided into three equal-sized areas, and the treatments (1) Low ground pressure, LGP, (2) Track Type Fleet, TT, and (3) Conventional large scale field equipment, WT, were randomly assigned to each of the three experimental units in the field. All fields were deep tilled in the fall of 1987 prior to initiation of the experiment. This was done to assure an "even start" in the fields with respect to residual compaction problems. Each field was subsequently farmed with equipment that did not exceed the maximum ground pressures assigned to each treatment. Fields were typically fall plowed with a moldboard plow, and leveled with a disc prior to winter. In the spring, anhydrous ammonia application was simulated, one field cultivation pass was performed, and the corn was planted with an eight row planter. Fertilizer and weed control was applied with a low ground pressure, belted application machine after planting for all treatments. At harvest, corn was harvested with a combine and grain wagon that met the ground pressure specifications for the respective treatments. Individual test fields ranged in size from 8 to 20 acres. Each field or plot was farmed as though there were a fence all around the area. End rows were planted and all traffic entered and departed through a "farm gate."

Yields of corn in the first two years of the study were adversely affected by drought. In 1990, the third year of the study, yields were affected by both wet conditions in the spring and dry conditions in late summer. Corn yields were much below normal yields for the farm for all three seasons. Figure 4 shows the yield results through 1990 for the fleet study. Results indicate a yield response increase of 14% and 19% respectively for the LGP and TT treatments over the WT treatment. This work will be conducted for at least two more years to determine if the trend will continue. There will also be at least one year when soybeans will be grown. Yield data for 1991 has not yet been analyzed.

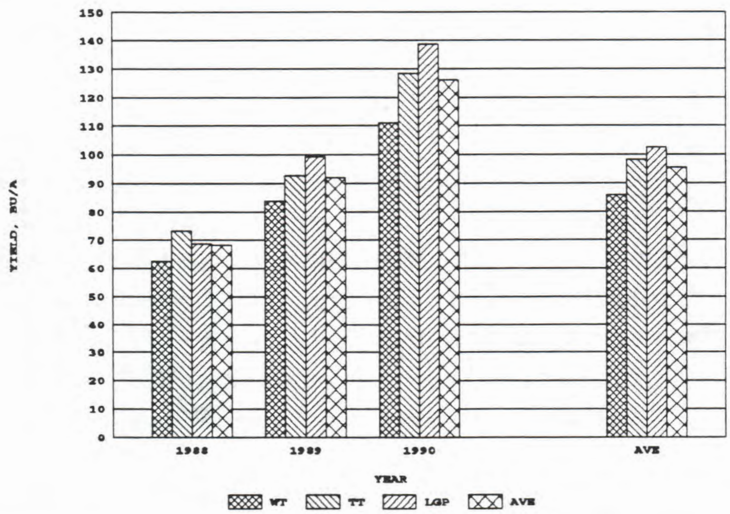

Figure 4. Corn yield results of fleet study. 1988-1990.

INTERNATIONAL AXLE LOAD STUDIES

In 1980, a committee of international scientists met in Sweden to recommend an experiment to be conducted in many parts of the world to determine the susceptibility of soils to yield reduction as the result of high axle loadings. This study has been replicated in many parts of Northern Europe and in the United States. Because we were working with various soils during compaction studies, it was decided to place the experiment on three different sites. This would allow us to compare the susceptibility of our soils to high axle loads compared to others around the world. The treatments include a 5-ton axle load which is used as a control. The international organization recommended a 10-ton axle load as a standard treatment. We included a 20-ton axle load at two sites and a 10-ton track loading as supplemental treatments. The 20-ton axle loading was included to represent axle loadings similar to large combines and grain wagons. The 10-ton track was a treatment to compare the effect of a tracked vehicle that would have approximately the same total weight as a 10-ton wheeled vehicle. The tracked vehicle used had a gross weight of 16.5 tons,but it represented the size of a wheeled tractor that would have approximately a 10-ton axle load.

Plots were prepared in the fall of 1989. The experiment calls for complete coverage of the plot area four times with wheelings from the appropriate axle loads. There was no tracking of the 5 ton, or control plot. However, all subsequent operations will be done with equipment with less than 5-ton axle loads. The compaction loads are to be placed in the fall following harvest when soil is at or near field capacity moisture content. The compaction loads are to be applied only once. The purpose of the experiment is to investigate the long term effects on crop yield on a "one time" compaction event. The soils at the sites were less than field capacity at each site in the fall of 1989. Moisture was near field capacity in the upper 2 feet of soil, but the profiles were less than field capacity below 2 foot depth.

The soil at the Wever site is a Chequest silt loam. The soil is a Kalona silty clay loam at the SE IA Research Farm and a Clarion-Nicollet complex at Ames. Past research has indicated that higher clay soils are more sensitive to compaction. None of these soils have clay contents above 35%. However, each has shown some evidence of spring compaction problems where soils have been trafficked in less-than-ideal spring soil conditions.

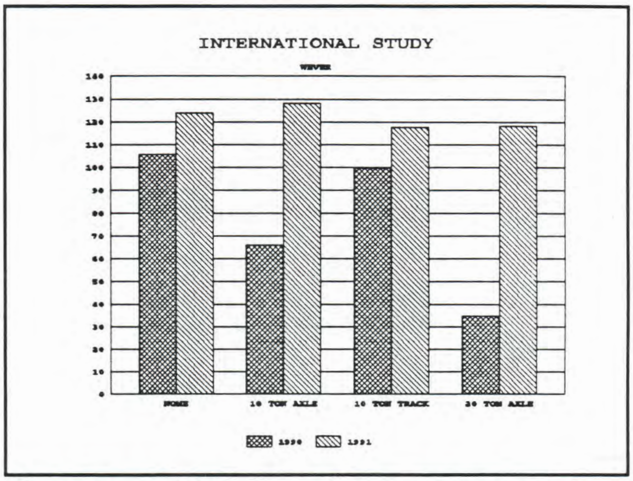

Figure 5. Yield results from axle load study at Wever, IA.

Figures 5, 6 and 7 illustrate the 1990 and 1991 yield response to a one time axle load placed in the fall of 1989 at the various sites. Yields in 1990 were most affected by heavy axle load treatment at the Wever site. At the other two sites, yields were less affected by the axle load treatments. At the Wever site, the tracked loading had a significantly lower yield reduction compared to the 10-ton axle loading. Both 1990 and 1991 were dry years at the Wever site. At the Southeast Iowa Research farm, excellent yields were obtained in 1990, but in 1991, the summer was exceptionally dry and yields were significantly lower. The 10-ton treatment at this site was slightly lower than the control for both years. The 10 track treatment was not significantly different than the control either year. At Ames, both 1990 and 1991 were similar in that there was sufficient early soil moisture, but a period of moderate drought stress in mid-summer. There was no treatment effect at Ames for either year. Plans call for continuation of this project for at least two more years.

There appear to be significantly different responses to a one-time compaction effort from these three different locations. However, there may be some effect of seasonal precipitation on the results. The corn has been stressed at all sites both years as a result of moisture deficit. The effect of compaction relief by soil cracking may lead to potential soil remediation.

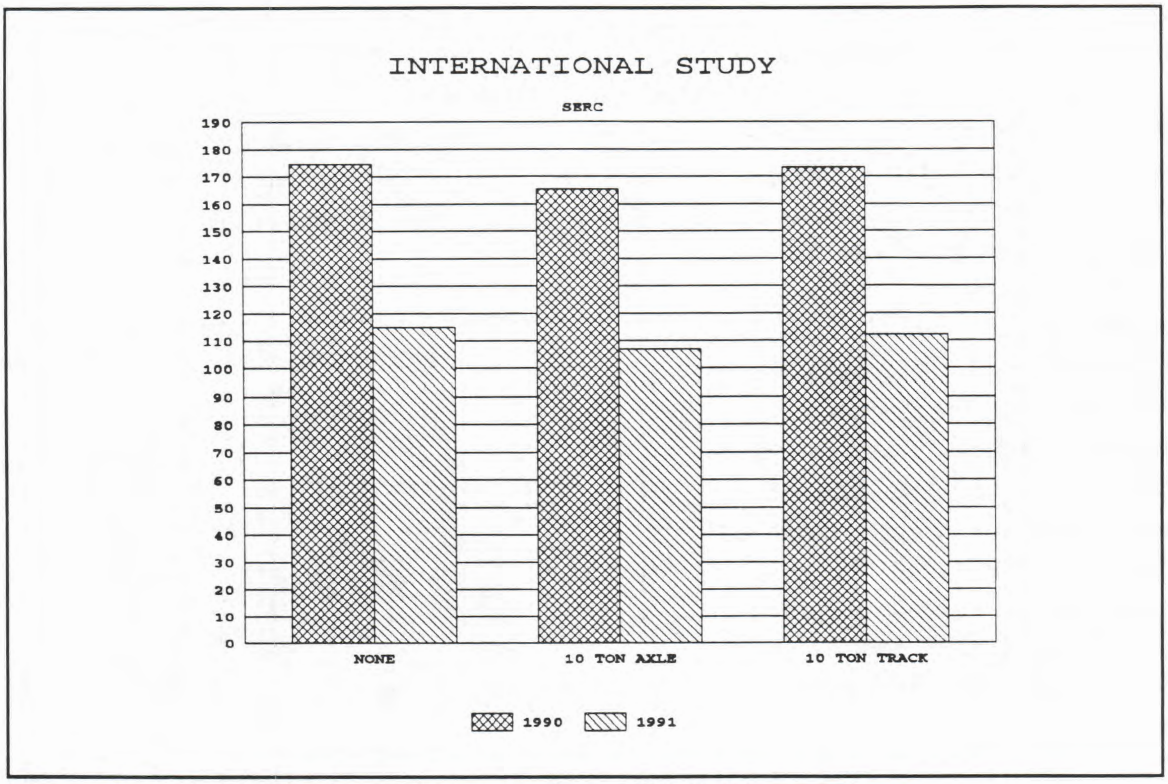

Figure 6. Yield results from axle load study at SERF, Wyman, IA.

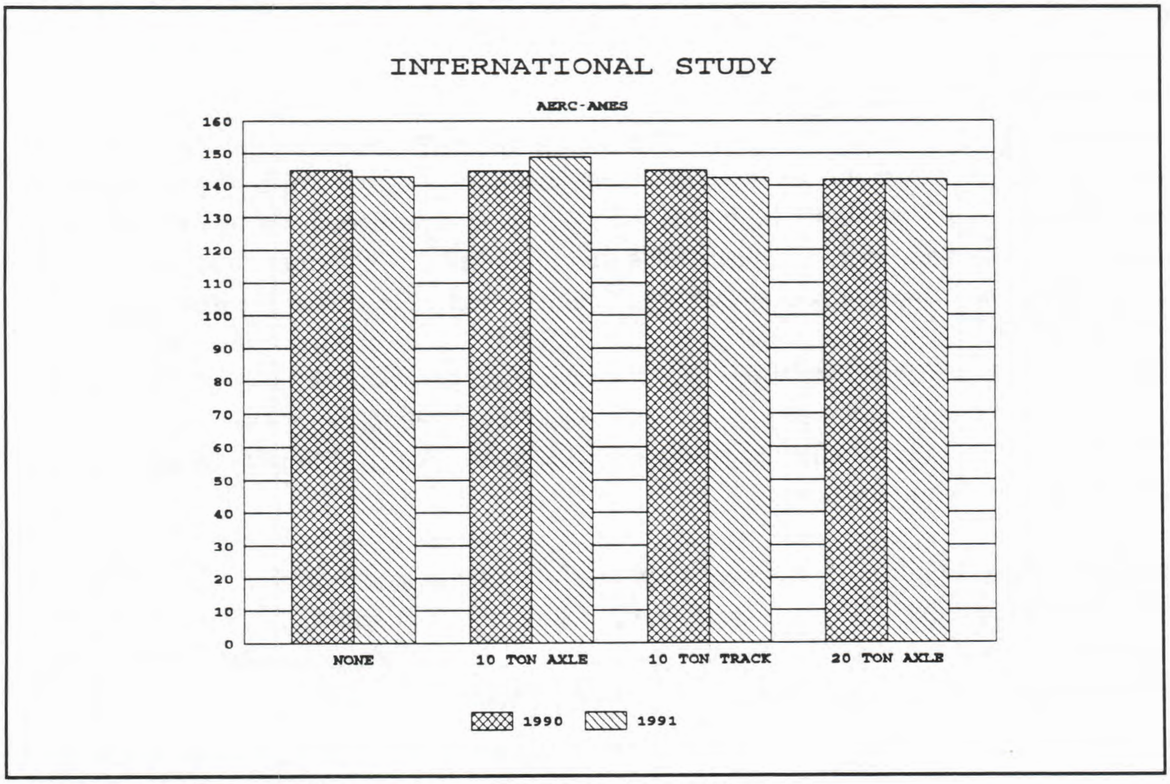

Figure 7. Yield results from axle load study at Ames, IA.

These plots also allowed us to investigate the effect of deep tillage (subsoiling) on (a) the potential for recompaction after deep tillage, and (b) the effect of deep tillage on crop yield subsequent to compaction.

SUBSOILING STUDIES

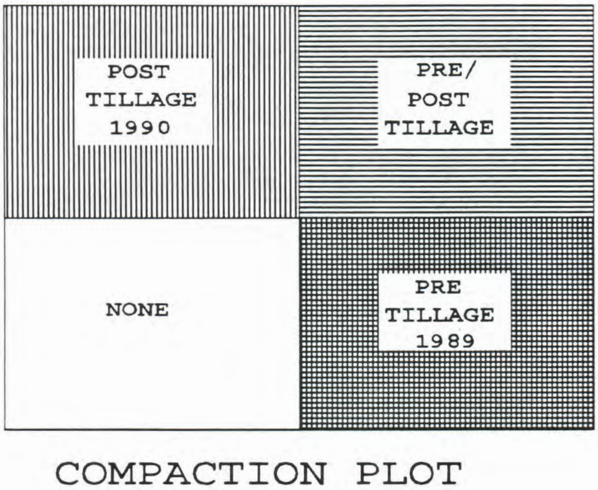

Figure 8. Layout of subplot subsoiling treatmen ts on axle load plots.

At two of the axle load experimental sites, the Southeast Iowa Research Farm and the Agricultural Engineering Research Center near Ames, plots were established to allow the comparison of four different subsoiling tillage treatments; (1) no tillage, (2) pre-tillage only before compaction of the plot, (3) post-tillage of the plot after compaction, and (4) both pre- and post-compaction tillage. Post-tillage treatments were done one year following compaction. Figure 8 illustrates the sub-plot arrangement. This experimental arrangement allowed data to be taken in crop year 1991 regarding the effect of post-compaction subsoiling in the plots.

Subsoiling results for 1991 are shown in figures 9,10, and 11. Figure 9 illustrates the yield results at Wever, where the plots were split only once since the entire plot area had been deep-tilled prior to axle loading. These results indicate that subsoiling appeared to improve yields for the 10-ton axle and the 10-ton tract treatments, but showed no effect for the 20-ton axle load treatment or on the check or 5-ton axle treatment.

In the other two plot areas, there was an added variable of pre tillage. Figure 10 shows the effect of the various subsoiling effects on the Southeast Iowa Research Farm. Precompaction subsoiling in 1989 appears to have reduced yields in the control plot in 1991, while having a possible benefit in 1990. Statistical analysis has not been performed on this data at the time of writing this paper, so conclusions should be drawn carefully. There appears to be a potential benefit of crop yield in 1991 from subsoiling in 1990 for the 10-ton and 10-ton-track treatments. However, the pre- and post-treatment appears to have had little effect.

Figure 11 shows the effect of subsoiling on the axle load treatments at the Agricultural Engineering Research Center. Subsoiling treatments appear to have increased yields from all axle load plots except the 10-ton track treatment. The most noticeable yield effect appears to be on the control or 5-ton axle load treatment where the pre- and post-subsoiling treatment appears to have increased corn yield.

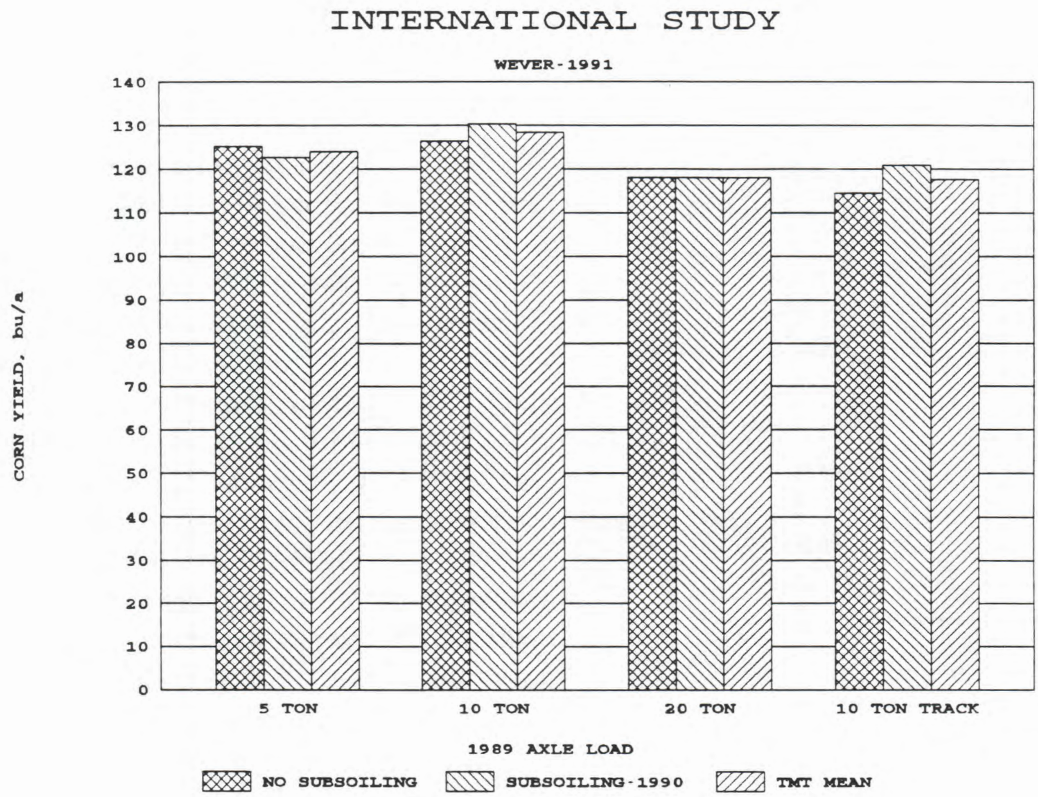

Figure 9. Effect of subsoiling on corn yield, Wever,IA.

SUMMARY

This paper reviews some of the past and present soil compaction research results in studies at Iowa State University. Some of the conclusions that can be reached based on these results are as follow:

1. Tractor traffic for spring tillage can result in significant yield reduction on sensitive soils.

2. Low ground pressure can be used as one technique to reduce the effect of compaction.

3. Some soils are more sensitive to heavy axle loads than others. Compaction effects can be masked by other crop growth factors such as moisture stress.

4. Subsoiling effects have been variable in tests run at Iowa State University and at other places in the Midwest. However, there appears to be some benefit under some conditions.

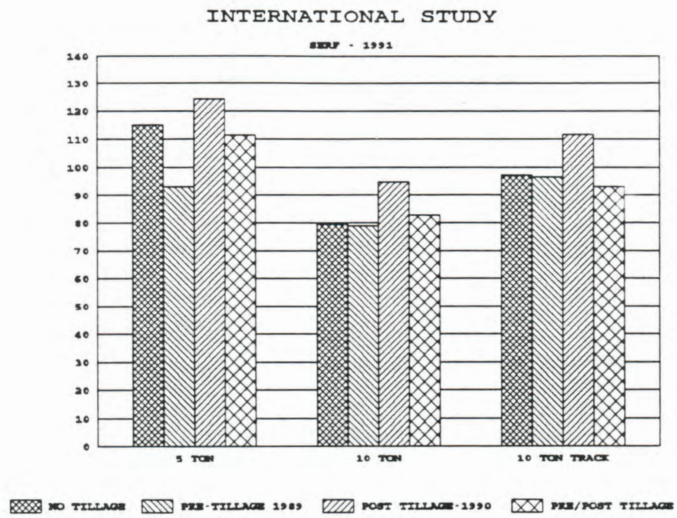

Figure 10. Subsoiling effects on corn yield,SERF-1991.

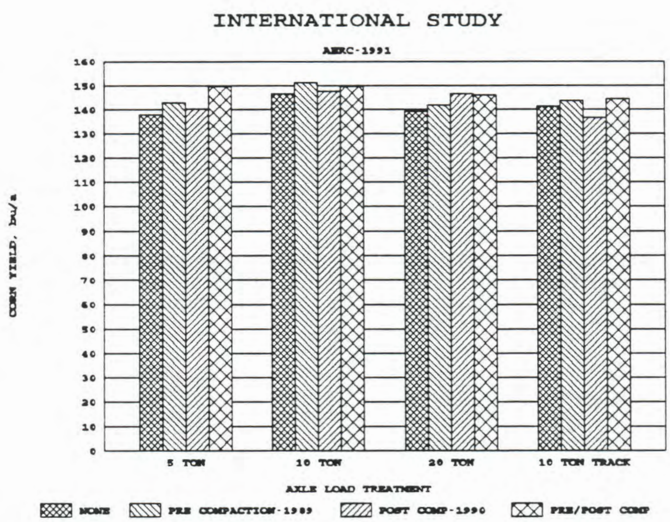

Figure 11. Subsoiling effects on corn yield, AERC-1991.